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Wastewater Treatment and Generation of Bioelectricity using Microbial fuel cell

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Abstract: **Microbial Fuel Cell (MFC) is a technology fed with microorganisms that mediate the conversion of chemical energy present in organic matter into electrical energy. MFC technology offers the potential to treat wastewater and generate power at the same time. In this research MFC was utilized to treat wastewater and generate bioelectricity. The wastewater sample was obtained from Dutse urban, Nigeria. MFC was run in fed batch mode for three cycles. Wastewater was treated by calculating the percentage removal of Chemical Oxygen Demand (COD). Voltage was measured using digital multimeter. Power and current density were calculated using ohms law. During wastewater analysis the MFC shows a reduction in COD by 82 % (Initial 680 ± 5 mg/L and final 120 ± 2 mg/L). The highest voltage in first, second and third cycles were 178 mV, 196 mV and 183 mV respectively, Power density was 18.26 mW/m^2 and current density was 97 mA/m$^{2..}$ The result obtained in this study can contribute to improve understanding on wastewater treatment and bioelectricity generation using MFC.**

Keywords: **Wastewater, Microbial fuel cell, Chemical Oxygen Demand, Treatment, Bioelectricity.**

1. INTRODUCTION

The release of sewage wastewater to the environment significantly causes pollution and human diseases. The hunt for alternative, clean energy technology has been pushed by the consequences of global warming on daily living and the depletion of fossil fuels (Nor *et al*., 2015). Developing nations require renewable energy sources to meet their current and future energy needs. Alternative renewable energy sources and technologies must be developed in order to overcome the effects of this pollution resulting from the human activities. The wastewater is initially pre-treated to remove the toxins and non biodegradable materials from the water (Parkash, 2016). This process is deemed challenging as wastewater can be extremely toxic and polluted undergoes extensive treatment before MFC can be used to clean the water. High operational sustainability and low material costs are important characteristics for treating wastewater efficiently (Ishwar *et al*., 2021). Microbial Fuel Cell (MFC) can partially meet the demand to treat those pollutants and at the same time generate electrical energy. MFC is a technology fed with microorganisms that mediate the conversion of chemical energy present in organic matter into electrical energy. MFC is consist of two chambers separated by a proton exchange membrane (PEM), the bacteria oxidizes organic substrates and produce electrons and protons (Hindatu *et al*., 2017). The electrons are passed through the external circuit whereas the PEM carries the protons to the cathode chamber. In the cathode chamber, protons and electrons react and oxygen is reduced to water (Hindatu *et al*., 2017). Bacteria are the driven force of MFC technology due to their innate capacity to break down organic matter and produce electrical energy. One of the unique advantage of MFC technology is that its environment friendly in nature as compared to other energy production technologies which involve methanogenic anaerobic digestion, fossil fuels which result in the emission of green house gas like carbon dioxide thus contributing to global warming (Du *et al*. 2007). Jigawa state is affected with problems of this pollution which have direct impact on human and the environment. This work has been able to profer solution to the aforementioned problem using the MFC to treat the wastewater and at the same time generate electricity from the wastewater.

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2. MATERIALS AND METHOD

Study Area

This work was conducted at Microbiology Laboratory of the Department of Microbiology and Biotechnology, Federal University Dutse, Jigawa State, Nigeria. The average temperature of Dutse varies from 54^0F to 103^0F, and is rarely below 49^0F or above 107^0F. Dutse is located at the latitude of 11.7024° N, 9.3340° E.

Sample Collection

All the sample bottles were washed and sterilized prior to sample collection. Wastewater sample was collected around Gida Dubu Area in Dutse, Jigawa State, while cow urine used as inoculum was collected from the cattle vendors in Dutse Jigawa state, Nigeria

Determination of Physicochemical Parameters.

Chemical Oxygen Dermand (COD), Total suspended Solid (TSS), Biochemical Oxygen Demand (BOD_5), pH, and Temperature were determined in triplicate as described by APHA, (2017).

Percentage of COD Removal

Wastewater treatment was analyzed by calculating the percentage of COD removal using the formula:

$$\text{Percentage of COD Removal (\%)} = \frac{\text{CODinitial} - \text{CODfinal}}{\text{CODinitial}} \times 100 \text{ ---------- Equation 1}$$

Construction and Operation of MFC

The construction of MFC was based on the previously constructed MFC described by Hindatu *et al*. (2017). Two PVC plastic bottles with a capacity of 250 mL each and working volume of 230 mL were employed during the MFC operation. The PEM (Nafion 117) was inserted between chambers and it was equipped with a rubber gasket to prevent leaking. The two chambers were connected by a plastic pipe with a diameter of 1.99 cm. The stainless steel mesh used for both anode and cathode electrodes were made of 4.4 cm diameter and 38 cm^2 surface area. A resistor (1000 Ω) was attached across the circuit and the two electrodes were clamped together using copper wire. Prior to operation, the MFC reactor was sterilized by cleaning it with distilled water, 3% sodium hypochlorite solution, and then further sterilized using ethanol. The anode chamber was filled with 210 ml sterile substrate and 20 ml broth culture of cow urine as inoculum, and the cathode chamber was filled with 230 ml phosphate buffer and kept open to air to maintain an aerobic environment (Moqsud *et al*., 2011). MFC was run in fed-batch mode, for three cycles, and readings were taken every 24 hours for a total of 36 days. After electricity generation, the contents of the MFC container was disposed and sterilized as previously mentioned. A new wastewater substrate without cow urine was used as control MFC. voltage was recorded at 12-hour intervals for a period of 10 days (Hindatu *et al*., 2018).

Calculations

The bioelectricity generated was measured using digital multimeter (DT-9205A), the voltage was measured across a 1000 Ω external resistor at 24 h interval. The voltage generated was used to calculate the current (I) Equation 2, current density (CD) Equation 3 and power density (PD) Equation 4 using Ohm's law as reported by Logan (2008).

$$I = \frac{V}{R} \text{ .... Equation 2}$$

$$CD = \frac{I}{ASA} \text{ …................ Equation 3}$$

$$PD = \frac{IV}{ASA} \text{ .... Equation 4}$$

Where ; V = Voltage, R = Resistor and ASA is the anode surface area (cm^2)

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Figure 1: Two MFC Chambers used during the MFC operation

3. RESULT AND DISCUSSION

Table 1: Physicochemical Properties of the Wastewater

S/No	Parameters	Values (mean ± SD)
1	pH	7.4 ± 0.2
2	Temperature (°C)	33 ± 0.7
3	BOD (mg/L)	457 ± 9
4	TSS (mg¯L)	40 ± 2
5	COD (mg/L)	680 ± 5

Keys; BOD = Biological oxygen demand, TSS = Total suspended solid, SD = Standard deviation COD = Chemical oxygen demand

Table 1 shows the characteristics of wastewater utilized as substrate in the microbial fuel cell. During the operation period of the MFC, the pH was stable at 7.4 ± 0.2 to support organism existence and to sustained the life of organisms, the BOD value was 457 ± 9 mg/L, the total suspended solids was found to be 40 ± 2 mg/L, COD was 680 ± 5 mg/L and the Temperature of 33 ± 0.7 °C. The high amount of the parameters values indicates that the substrate contains sufficient amount of biodegradable organic compounds, which can serve as a rich source of energy for the microbial communities in MFCs (Bose *et al*., 2018).

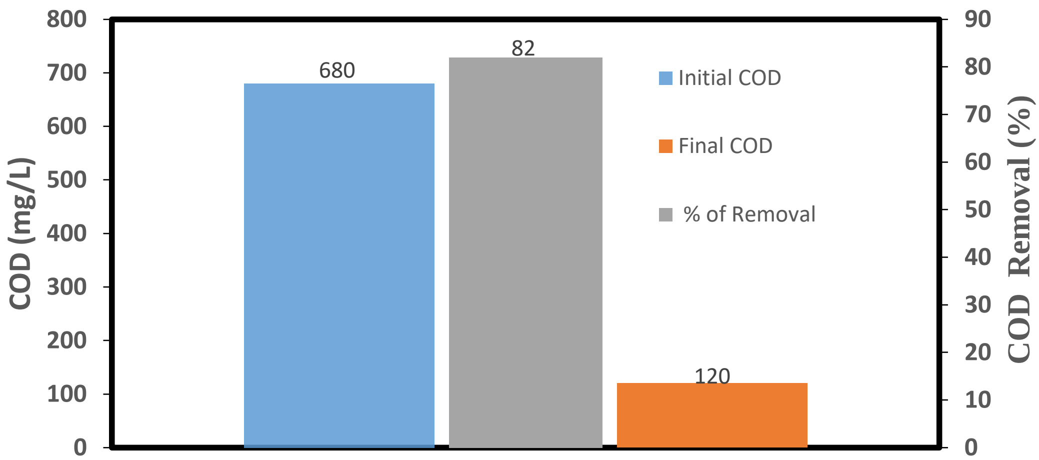

Figure 2: Removal of Chemical Oxygen Demand in Percentage

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Figure 2 showed the percentage of COD removal. COD removal efficiency was reduced from an initial 680 ± 5 mg/L to 120 ± 2 mg/L within 36 days of MFC operation, yielding an overall removal efficiency of 82 %. The reduction in COD indicates that the microorganisms in the MFC were effective in breaking down the organic matter in the wastewater, transforming it into electricity. The system's power generation enables faster COD consumption rates, lower loss to background activities, shorter time requirements, and higher COD removal rates (Bose *et al*., 2018). After about a week of MFC operation, the current density and rate of COD removal rapidly decreased thus the system was not producing enough current when the current density dropped off quickly. Liu *et al*. (2004) stated that power generation ought to go on until all of the COD has been used. As shown in figure 2, at higher COD rate the voltage was very high, but once the COD start declining the voltage also was very low, when the COD value reaches 120–110 mg/L, the MFC stop generating current completely, which showed that COD levels was too low to generate bioelectricity and thus indicating that wastewater was treated and can safely be discharged in to the environment (Logan, 2008).

Generation of Bioelectricity

After 36 days of MFC operation, the MFC's performance was evaluated in terms of voltage recorded over time (Figure 3), it was discovered that the MFC's fed batch mode could produce electricity from concentrated wastewater produced by microbial communities. Following three to four days of acclimatization, a consistent rise in voltage and current was noted. The quick rise in voltage is due to the microorganisms acting as biocatalyst in the MFC (Kundu *et al*., 2015).

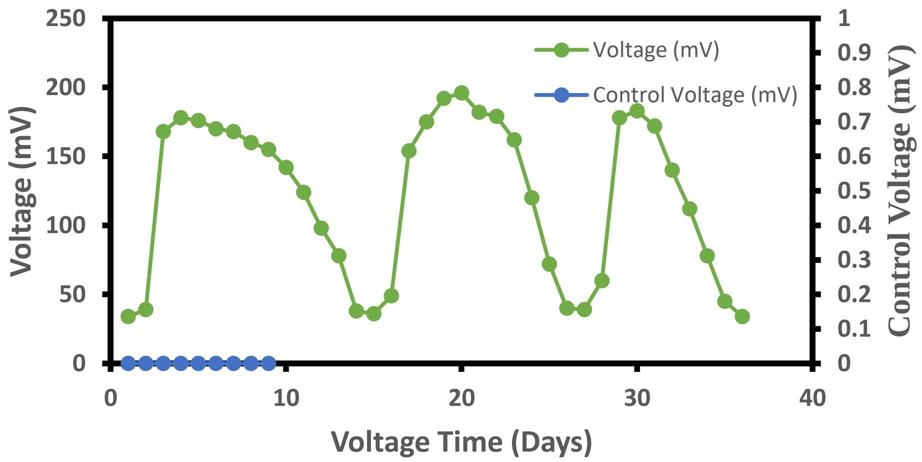

Figure 3. Voltage generated for the three cycles of MFC

As shown in Figure 3 The highest voltage for the first cycle was 178 mV, second cycle was 196 mV and the third cycle was 183 mV with the addition of new substrate at the end of each cycle. Following the achievement of the stable voltage, the maximum current density and power density achieved were 97.11 mA/m^2 and 18.26 mW/m^2 respectively. This indicate that the voltage was mainly stable throughout the operation of MFC with gradual decrease toward the end of the operation. In general, the electricity generated increased and reach its peak on the first few days after which it decreased gradually. This indicate that microorganism in the anode start to function effectively as soon as their nutrient source is replaced. This is in agreement with the research of (Onilude *et al*., 2013) using cow urine and wastewater to generate electricity in MFC. The control MFC was also operated with only sterilized substrate excluding the broth culture of cow urine, all operational parameters were the same with the experimental MFC voltage reading was zero throughout the period of the experiment. This indicate that microorganism are the driven force for the electricity generation.

4. CONCLUSION

This study focused on using MFC to treat wastewater and generate electricity from wastewater using cow urine as inoculum. Overall COD removal of 82% was achieved. The maximum voltage of 196 mV, current density of 97.11 mA/m2, and power density of 18.26 mW/m2 were also achieved. The result obtained in this study can contribute to improve understanding on wastewater treatment and bioelectricity generation in MFC.

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